MODULE 1

THE COASTAL ECOSYSTEM AS A RESOURCE BASE

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OBJECTIVES:

- To give an overview of the types of marine ecosystems in the Caribbean Region.
- To identify major ecosystems that are impacted by tourism-related activities.

OVERVIEW:

- Outlines the ecosystem approach to tourism management.
- Establishes differences between marine and terrestrial ecosystems.
- Outlines measures required for effective management and conservation of marine coastal ecosystems.
- Describes major coastal ecosystems relevant to the tourism industry in the Wider Caribbean.

THE CARIBBEAN COASTAL ZONE

Integrated Coastal Area Management (ICAM) as an approach has evolved from the growing threat to the health of coastal ecosystems from user demand and inappropriate practices. The coastal area encompasses the land-sea interface, and therefore its terrestrial and marine resources. The Caribbean region relies heavily on its coastal areas and therefore coastal ecosystems is a basic resource, which provide services to support the tourism industry, mostly based on the coastal zone in the Caribbean.

The health of the tourism industry is therefore a function of the health of coastal ecosystems. Consequently it is imperative that the tourism sector be an active player in the management of the coastal zone.

The coastal zone of the Wider Caribbean which includes islands and coastal areas of the continental countries is home to some 80 million residents and 20 million visitors. Coastal areas in the region are threatened by over-exploitation of marine and terrestrial resources, poor management practices, conflicting user demand and inadequate land use planning. Increasingly dense settlements with inadequate infrastructure serve to exacerbate the growing threat to the viability of coastal ecosystems, the foundation on which the growing tourism industry is built. These ecosystems are the basis of the Caribbean's marine productivity and high biodiversity.

Management of the coastal zone must be based on an understanding of coastal ecosystems and their function, the services which they provide, the land use, settlement characteristics and economic activities and the interaction of all these components.

DEFINITION OF THE ECOSYSTEM APPROACH

The Conference of the Parties to the Convention on Biological Diversity adopted an ecosystem approach for the implementation of the objectives of the Convention. This was endorsed by the General Assembly of the United Nations in June 1997. Twelve principles of the ecosystem approach were highlighted. These are complimentary and interlinked, and together they characterize the ecosystem approach. The ecosystem approach should include a system of accountability which specifically addresses the performance of managers and decision-makers and the achievement of management objectives. These objectives are outlined below with a brief explanation of the rationale behind each:

- Management objectives are a matter of societal choice - societies view ecosystems in terms of their own economic, cultural and social needs.
- Management should be decentralized to the lowest appropriate level - decentralized systems can lead to greater efficiency, effectiveness and equity.
- Ecosystem managers should consider the effects of their activities on adjacent and other ecosystems - interventions in ecosystems often have unknown or unpredictable effects on other ecosystems and need careful consideration and analysis.

- **There is a need to understand the ecosystem in an economic context** - the greatest threat to biological diversity lies in its replacement by alternate systems of land use, and those who benefit from conservation rarely pay the costs associated with it and those who generate environmental costs often escape responsibility.

- **A key feature includes conservation of ecosystem structure and functioning** - ecosystem functioning and resilience depends on a dynamic relationship within, among and between species and their abiotic environment as well as physical and chemical interactions within the environment.

- **Ecosystems must be managed with in the limits of their functioning**- attention must be given to the environmental conditions which limit natural productivity, ecosystem structure and functioning.

- **Should be undertaken at the appropriate scale** - the approach should be bound by spatial and temporal scales that are appropriate to the objectives.

- **Objectives should be set for the long term** - ecosystem processes are characterized by varying temporal scales and lag effects which inherently conflicts with the human tendency to favour short term gains and immediate benefits.

- **Management must recognize that change is inevitable** - ecosystems have an inherent dynamism and adaptive management must be utilized in order to cater for changes.

- **Seek an appropriate balance between conservation and the use of biological diversity** - past management of biological diversity has been in the context of protected or non-protected and there is a need to switch to more flexible situations.

- **Consider all forms of relevant information** - information from all sources is critical in order to reach at effective management strategies, including scientific, indigenous and local knowledge.

- **Should involve all relevant sectors of society and scientific disciplines** - most problems of biological diversity management are complex with many interactions and implications.

MARINE ECOSYSTEMS

Marine ecosystems physical parameters include the following components:

- salinity
- type of bottom
- water temperature
- currents
- tides
- wave action

The biotic components of marine ecosystems include the diversity of plants, algae, animals and microorganisms which are present. The nutritional demands, reproduction requirements and living space, and the ways or behavior to acquire these are the biological processes. The population size is an element of equal importance.

Marine ecosystems differ significantly from terrestrial ecosystems in the relationship they have with the liquid medium by which they are surrounded. Organisms are less connected to the solid substrates in marine ecosystems - with exception of those organisms which inhabit the drier portions or less humid coasts and are attached to the substrates below the shore line - than organisms in terrestrial ecosystems. In addition, marine organisms, as a result of being submerged in the liquid matrix, are in direct contact with the chemicals which are dissolved in the water and as such are more vulnerable to contaminants and pollutants. At the same time the fluid component of the marine environment - the existing currents, waves and tides - also provide for larger mobility of organisms than in terrestrial systems. Extreme examples of this effect are the large planktonic communities which float and are transported with the currents along large distances all around the earth.

The coastal areas can be considered an interphase between three spatial communities: land, air and sea. This is not a static interphase, but an extremely dynamic one especially with relation to the interaction of the land and the sea. Dramatic changes can occur in these coastal areas as a result of volcanic eruptions and hurricanes, storm surges, and tsunamis where the effect can modify the coastal marine environment.

More subtle, constant and continuous changes such as tides, currents and normal wave action can provoke alterations to the coast, at a specific site. The natural form of the coast line is determined by its composition, geological structure, weathering processes, drainage patterns, coastal topography, hydrography and by the relative levels of the land and water.

The management of coastal resources which involves the interactions of these three types of habitats, is not an easy task. Management decisions which are applied to an inland forest are not effective for managing a mangrove forest, even if this community is also a forest composed of different species of mangrove trees. The general differences between terrestrial and marine ecosystems which have been mentioned above, requires that different measures of management and conservation be considered for marine coastal systems

IDENTIFICATION OF COASTAL ECOSYSTEMS

In coastal areas at least two habitats or environments are obvious: the marine and the terrestrial zones. This manual focuses on the ecosystems in shallow coastal waters, from the shoreline to a depth of 30 meters. This is the littoral zone.

The main coastal ecosystems of importance to tourism in the Wider Caribbean region are: the coral reefs, dunes and beaches, estuaries, sea grass beds, wetlands and mangrove forests.

CORAL REEFS

Coral reefs are an exclusively tropical ecosystem - found between latitudes, 28° North and 28° South. Coral reefs are considered to be the most productive of all ecosystems.

The hard corals - also called stony corals form the basic structure of the coral reef. Coral reefs are made of animals with simple tubular bodies, - called polyps - which have the biological capacity to form a hard external skeleton made of calcium carbonate from which an extensive submerged barrier can be formed. The health of coral reefs is dependent on clean, clear water and consistently warm temperatures.

There are different types of coral reefs, described by their shape & spatial orientation:

1. Fringing reefs - this type of reef forms a platform which is continuous along the shore line. The fringing reef is the most common type of coral reef and their relative closeness to the shoreline makes them vulnerable to impact from terrestrial activities.

2. Patch reefs - are small islands or interrupted cays, located far from the shore.

3. Barrier reefs - are extensive structures - hundreds of kilometers - which follow shore lines. The Great-Barrier Reef along the coast of Queensland, Australia is the largest in the world, while the largest in the Western Hemisphere is found off the coast of Belize, Mexico and Honduras.

4. Atolls - These are circular or semi-circular reefs which are outgrowths of corals on submerged volcanoes.

Reef - forming corals are slow growing organisms and the annual growth of a reef is from 1/10 cm to 10 cm. Corals are small carnivorous animals that capture food with their tentacles. In their evolutionary history, they have established a symbiotic relationship with microscopic algae known as zooxanthellae (dinoflagelates) which live in the tissues of individual polyps. It has been determined that the zooxanthellae play an important part in the corals' capacity to form its hard skeleton of calcium carbonate. Zooxanthellae are organisms which are photosynthetic, requiring a certain amount of light to produce their food. Because of these needs, reef forming corals need clean and transparent waters for survival.

The coral reef ecosystem is not only made up of hard corals, but also soft corals. Additionally, a solid structure, offers adequate surfaces for many organisms such as mollusks, worms and algae to establish themselves and grow. Spaces between different forms of reef and dead corals form caves, fissures and dwellings which are occupied by other organisms such as different species of fish and crustaceans.

The nutrient relationship between inhabitants of the coral reefs can be very complex, involving a great diversity of species in different levels of nutrient and energy transfer - from the zooxanthellae and planktonic algae up to the higher levels in the food chain, such as sharks. The majority of seafood and fish which are of commercial importance to the fishing industry in the Caribbean are species associated with coral reefs.

Coral reefs constitute the marine ecosystem with the largest levels of biodiversity and are important sources of biological productivity in coastal waters. They also offer a key and effective barrier against beach erosion by absorbing the energy of the waves acting as breakers.

Damage

Coral reefs are subject to considerable degrading impacts both natural and anthropogenic. These include earth tremors, storms and water temperature changes which are all natural phenomena which can damage reefs. Without human intervention, reefs are able to recuperate from the ravages of natural disasters such as hurricanes.

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The community of reefs can also be subject to physical damage by anchors from both recreational and commercial fishing boats. Mechanical damage can also be caused by divers and snorkelers standing on and holding live corals. This type of physical damage has a larger and more extensive negative impact than natural phenomena.

Over-fishing and selective fishing of certain species can also affect reef growth and structure as a result of ecological changes.

Water Quality

Apart from sedimentation which can be caused by construction practices on land, changes in the quality of the water can also occur by contamination from untreated domestic wastewater, petroleum and its derivatives, pesticides, fertilizers, and other toxic substances. These can cause coral loss to such an extent that the corals are unable to recuperate. The mechanical breakdown of the hard skeleton of calcium carbonate make up the fine particles of white sand which forms most of the beaches in the Caribbean.

DUNES AND BEACHES

For the purpose of this Manual two ecosystems - dunes and beaches (although governed by ecologically distinct attributes), must be seen as an important unit of the lower coasts. These are dynamic features of the coast line as they are subjected to continuous movement of sand particles. The changes in shape and contour of a beach and its dune are noticeable at different periods of the year. At high tides beaches change their contours with an increase in the slope. Strong winds which blow offshore, push back the sand toward the beach, thus reducing the angle of the inclination.

Sand deposits brought down from mountainous areas via rivers and creeks also contribute to the formation of dunes and sandy beaches. The wind, waves and marine currents along the coasts are the responsible agents for distributing the sand all along the coasts. Wind currents are the main factor in dune formation. With time, a plant community composed of vines, grasses and shrubs can establish itself over the dune. This vegetative community contributes to stabilizing the dunes while protecting its sand deposits.

Extraction of sand from the dunes and beaches for the construction industry is a major negative impact for the conservation of these ecosystems. The construction of piers, wave breakers, and ramps for boats, and dredging without considering the dominant patterns of shore line currents in the zone which supply and transport sand along the coasts, can result in accelerated erosion of beaches.

In ecological terms, dunes and beaches can be considered relatively inhospitable habitats because of the instability of the substrate. Nevertheless, this does not mean that plants and animals of diverse species with different adaptations in body, behaviour and biological functions cannot tolerate the constant movement of sand deposits. Different species of molluses, crustaceans, and annelids which possess shells or hard carapace or form their own protective tubes with sand can live buried in the sand or between sand particles.

Beaches and dunes behind them, represent the immediate line of defense of the coastal valleys against erosion, especially on the coasts which do not have protection from a coral reef or mangrove forest. The loss of beaches and dunes have serious consequences among which is the immediate erosion of the coast line, resulting in saline intrusion and the alteration of soils reducing its high agricultural potential.

MANGROVES

Mangrove forests are coastal forests formed by different species of trees commonly called 'mangroves,' which have the special capacity to withstand high salt concentrations and fix their roots in loose soils. Like coral reefs, mangroves are exclusively tropical ecosystems. The main species of mangroves in the Caribbean region are: the red mangrove (Rhizophora mangle), the black mangrove (Avicennia germinans), the white mangrove

(Laguncularia racemosa) and the button mangrove (Conocarpus erectus). All these species occupy a boggy fringe along the edge of the coast. The red mangrove, is found directly in contact with the sea, while the black and white mangrove occupy marshy areas in the interior. The button mangrove occupies the driest and highest part of the coast.

The morphological and physiological adaptations of the mangroves permit them to colonize areas of the coasts which other species are unable to inhabit. The red mangrove is able to filter sea water, removing the salt, which would be toxic to the plant. The black and white mangroves also possess structures in their leaves which permits them to eliminate the excess salt that enters with the water through their roots. The red mangrove possess a root system in the form of stilts called prop roots which permits it to find support in completely unstable substrates. The black and white mangroves produce respiratory roots called pneumatophores which grow above the inundated soil and permit the exchange of gases between cells in the roots and the atmosphere. The red mangrove has pores or lenticels in its roots for the same purpose.

The ecological role that the mangrove forest plays as an ecosystem, has great value not only as a keystone ecosystem but also foreconomic and social reasons.

Of all the coastal ecosystems, mangrove forests have one of the highest demands for use.

Mangrove forests have a high level of productivity and play an important role in the transformation of organic material and the transport of nutrients and energy.

Many species of fish, shrimp, mussles and oysters, all of high commercial value, depend on the transfer of nutrients from the mangrove forest. The lagoons inside the mangrove forest also provide an important habitat by serving as nesting sites for aquatic birds, reptiles and other aquatic fauna.

During the hurricane season in the Caribbean region, (normally July to August) mangroves act as a buffer against winds, storm surges and waves, protecting the land mass from destructive forces. The prop roots of the red mangrove, which form a complex interweave at the base of the trees, contribute by forming an effective method in reducing the energy of the sea, retaining sediments, stabilizing the coast line and preventing and retarding.

Of all the coastal ecosystems, mangrove forests have one of the highest demands for use and consequently receives a high level of anthropogenic negative impact. The space occupied by mangrove forests are generally viewed as swamp areas, unhealthy, and used for disposal of domestic and industrial waste. As such, they are converted to dumps for solid waste and receive sewage effluents from cities in many instances.

Mangroves are located in low level plains, and are often filled or drained which changes the topography of the land, alters the ecosystem and creates land of high commercial value. Mangroves are often used as firewood and forests have been cleared for the construction of fish ponds or mining of peat as an alternative energy source.

SEA GRASS BEDS

Marine grasses are species of plants with leaves, stems, flowers or angiosperms.

The marshy bottoms of low level waters, between mangrove forests and coral reefs waters are often colonized by different species of marine grasses. These are species of plants with leaves, stems, flowers or angiosperms. Although their origin is terrestrial, these species have adapted to a submerged saline environment. These are found in shallower waters up to 25 meters depth. Since these are photosynthetic organisms, they depend on clear water which allow the penetration of sunlight.

Even though these are not taxonomically true grasses - their type of growth and leaf structure have resulted in the popular name 'sea grasses.' The turtle grass (Thalassia testudinum) and the manatee grass (Syringodium filiforme) are the most abundant seagrass species in the Caribbean Sea and the Gulf of Mexico. The turtle sea grass dominates plains, and thus these are often referred to as 'Thalassia beds' although other species of grasses are also found at the same sites.

Thalassia possesses a creeping stem or rhizome, and a fibrous root system which permits it to form a sort of thick cushion carpet on the slimy bottom where it grows.

Marine grass plains have a high level of primary productivity, as a result of their own photosynthetic activity but also because of the other photosynthetic organisms which live on the leaves of the Thalassia. Seagrass beds are found between mangrove forests and coral reefs they provide the connection between these two coastal ecosystems serving as an important example of the complex linkages between coastal ecosystems which are vital to the maintenance of their ecological integrity. Many species of fishes and other organisms associated with coral reefs and mangroves move to sea grass plains using it as habitat at some stage of their life cycle or even daily for feeding purposes.

Commercial fishing and recreational boats damage sea grasses by tearing them from the substrate.

Sea grasses are subject to negative impacts from human activities along the coast line. One impact is from the increase in the quantity of sediments along the coast which increases turbidity in the water and decreases light penetration that is needed for their growth. Commercial fishing and recreational boats damage sea grasses by tearing them from the substrate. Anchors from boats also leave large scars in the plain which are often not recognized or restored. Since sea grass plains are much less obvious as compared to mangrove forests, their loss is frequently not noticed.

Sea grass beds provide an important ecological service to coastal ecosystems. As a result of their shape and growth pattern they are extremely efficient in the stabilization of soils between mangroves and the coral reef. They also trap much of the sediment which is washed from the terrestrial environment or from the mangroves and would be harmful to the corals. Sea grasses occur in calm waters and serve as breeding areas as well as providing protection for juveniles of many species and pasturing sites for adults of some species such as fish, turtles and manatees.

ESTUARINE SYSTEMS

Estuarine systems include the coastal bodies of water, plains, enclosed or semi-enclosed lagoons, small bays and marshes at the mouth of rivers. Salinity ranges from low (fresh water), to brackish or high salinity waters indicating truly marine conditions. The diversity of estuarine habitats present in a region will depend on several factors including the geology of the area, topography of the land, rainfall and ocean currents.

The organisms which inhabit estuaries are adapted to daily and seasonal salinity fluctuations. The introduction of fresh water from inland water sources, the introduction of saline water with the changes in the tide levels and the cyclic pattern which are established in the coastal lagoons are, in part, responsible for the high biological productivity of these ecosystems.

Of all the coastal ecosystems, estuaries, including mangrove forests in general, probably receive the largest quantity, diversity and intensity of anthropogenic impact.

These littoral basins, which can take many different shapes, are of great importance in the life cycle of many animals which inhabit seas far from the coasts because they provide sites for breeding, reproduction and feeding in different stages of the life cycle. The level of productivity in coastal areas, depends on the estuarine ecosystem of the coasts. An example is the fisheries in the Gulf of Mexico. Another ecological service these systems provide is the exportation of nutrients to the ocean.

These littoral basins, which can take many different shapes, are of great importance in the life cycle of many animals which inhabit seas far from the coasts because they provide sites for breeding, reproduction and feeding in different stages of the life cycle. The level of productivity in coastal areas, is linked to estuarine ecosystems. Another ecological service these systems provide is the exportation of nutrients to the ocean.

Of all the coastal ecosystems, the estuaries, including mangrove forests in general, probably receive the largest quantity, diversity and intensity of anthropogenic impact. These impacts may result in alteration of water circulation patterns from land to coast and the desertification of watered areas. Estuaries are also used as a repository for all types of contaminants from industrial and domestic wastes. The pollution impacting estuaries and adjacent ecosystems often points to the ignorance of the importance of these coastal ecosystems.